

# Internal Correspondence



To: Bert Howard, Ethan Blaszczak

AVO 11-F1-1038

Fm: Eric Neyhard

Re: S-92 T/R Pitch Beam Locking Washer and Nut Installation Test

Dt: February 3, 2011

cc: Richard Hood, Evan Sobel, Owen Stein, Clemente Mascola, Teofilo Garcia, Christopher Lowenstein, Clifford Smith

## Background

During an S-92 customer flight on Aircraft 88, the pilots lost tail rotor (T/R) authority and were required to perform a run-on landing. Upon landing it was discovered that the T/R pitch beam retention nut and associated hardware were missing from the assembly. The pitch beam and pitch change shaft from the incident aircraft were analyzed in the Stratford Materials lab and results indicated that the locking washer was not properly installed on the pitch change shaft. Witness marks on the pitch change shaft spline end faces and on the pitch beam show that the locking washer may have been installed with the indexing spline slightly off, resulting in a cocking condition and incomplete engagement of the spline teeth.

Rotors Engineering and the National Transportation Safety Board (NTSB) took corrective action to introduce additional safety features into the T/R design and the installation procedure of the T/R pitch beam. As part of their actions, a test request was created to evaluate the conditions following the incorrect installation of a locking washer and pitch beam retention nut. The test was performed in the Stratford Fatigue Lab on February 1<sup>st</sup>, 2011, and the results will be used by Engineering to modify components and procedures as needed. Refer to latest revision of Engineering Instruction (EI) E92-725-10-136 for additional details.

## Test Design and Results

1. Procure T/R pitch beam, locking washer, retention nut and required hardware
2. Using a black marker, mark the faces and edges of the locking washer and pitch beam at the indexing spline as shown below:

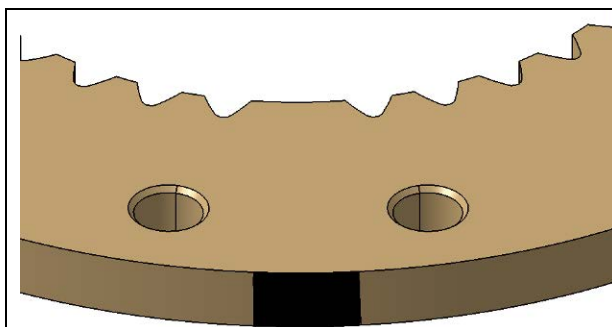


Figure 1 - Locking Washer Mark on Index Tooth

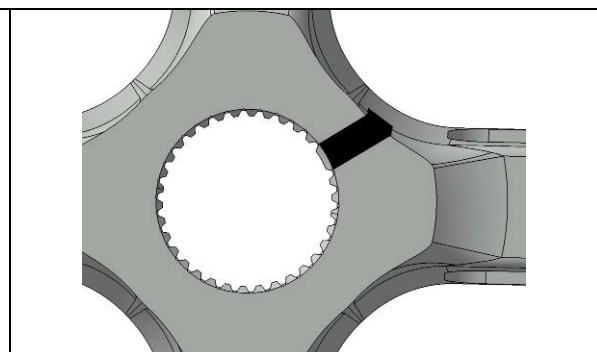


Figure 2 - Pitch Beam Mark on Index Tooth

3. Prepare T/R test facility in fatigue lab for installation of T/R pitch beam and retention hardware
4. Coat all mating surfaces of pitch beam, locking washer and retention nut with CA1000 sealant, taking care not to apply the sealant to the spline teeth
5. Install T/R pitch beam onto pitch change shaft
6. Install the locking washer CORRECTLY onto the pitch change shaft by aligning the index wide tooth on the locking washer with the index gap on the pitch change shaft. The black marks drawn on the parts in Step 2 should be aligned.
7. Install the retention nut and hand tighten against the locking washer. Measure the height of the shaft thread protruding from the top of the retention nut. Record values in Table 1 below:

Table 1: Thread Protrusion Zero Torque

<b>Maximum Height =</b>	0.068"
<b>Minimum Height =</b>	0.062"

8. Using a calibrated torque wrench, tighten the pitch beam retention nut to the torque values below and record the amount of rotation visible between the locking washer and the retention nut.

Table 2: Torque Steps and Rotation Values (Correct Installation)

<b>Torque (ft*lbs)</b>	<b>Total Rotation (Inches around Circumference)</b>
0	0.00
60	2.12
120	3.25
183	4.00
202	4.25

9. With pitch beam retention nut correctly installed and tightened to a torque value of 202 ft\*lbs, record the pitch change shaft thread protrusion once again:

Table 3: Thread Protrusion Max Torque

<b>Maximum Height =</b>	0.091"
<b>Minimum Height =</b>	0.083"

10. Loosen the retention nut far enough such that the locking washer can float freely above the pitch change shaft spline teeth.
11. Rotate the locking washer at least one gear tooth such that the shaft and washer index splines (and the black marks) are no longer aligned. Hand tighten the retention nut while the locking washer is misaligned on the gear teeth and one side of the washer is cocked up off of the pitch beam face.

12. With the locking washer INCORRECTLY installed, tighten the pitch beam retention nut to the torque values below and record the amount of rotation visible between the locking washer and the pitch beam.

Table 4: Torque Steps and Rotation Values (Incorrect Installation)

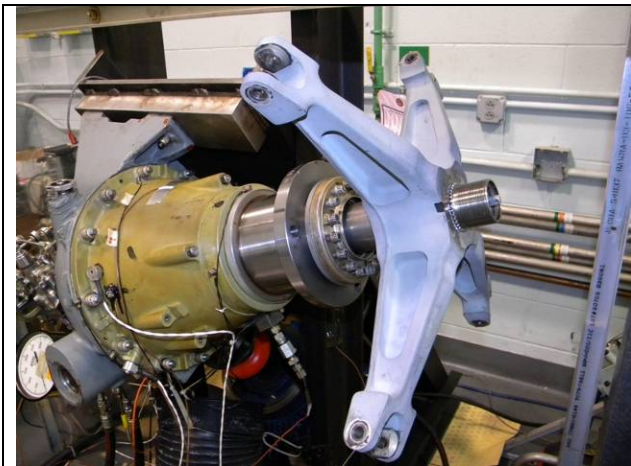
<b>Torque (ft*lbs)</b>	<b>Total Rotation (Inches around Circumference)</b>
0	No visible rotation
60	No visible rotation
120	No visible rotation
183	Very little rotation (<0.10")
202	Very little rotation (<0.10")

13. Record the height of the protruding shaft threads here: -0.030" (negative threads)  
 14. Record the maximum height of the gap between the locking washer and the pitch beam face here: 0.121"  
 15. Remove retention nut, locking washer and pitch beam for inspection of spline damage. Clean parts with alcohol wipes to remove CA1000 prior to taking post-test photographs.  
 16. Return all test parts to Materials Lab and Engineering for further analysis.

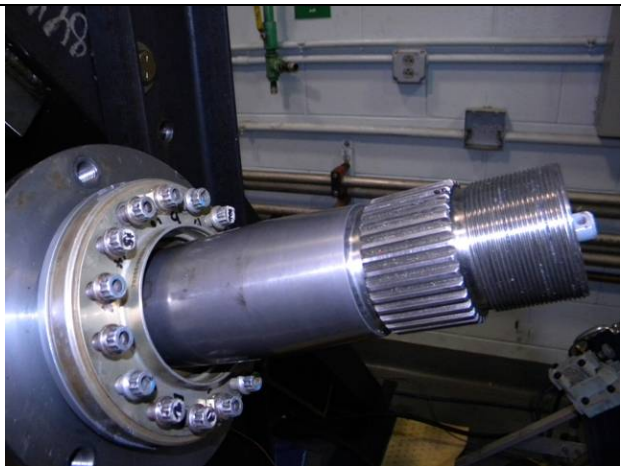
### Test Observations

With CA1000 applied to all mating surfaces of the locking washer, it was markedly simple to cause a misalignment of the locking washer on the spline and have it partially engage the shaft teeth as the retention nut was rotated and tightened. With the locking washer misaligned, it turned approximately 90° clockwise as the retention nut was being preloaded. At that point (less than 10 ft\*lbs torque), the locking washer partially engaged the spline teeth and remained in the cocked condition until the full 202 ft\*lbs of torque were achieved. The gaps created by the cocked condition were easily visible (and measureable) and can be referenced in an added Engineering safety procedure, if necessary. The post-test condition of the teeth on the locking washer included barely visible evidence of the misalignment against the shaft splines. However, the test damage did not include the same deformation of the shaft splines that was apparent on the incident aircraft due to the dynamic forces present. The recommended safety procedures realized during this test are included in the latest revision of Engineering Instruction (EI) E92-725-10-136.

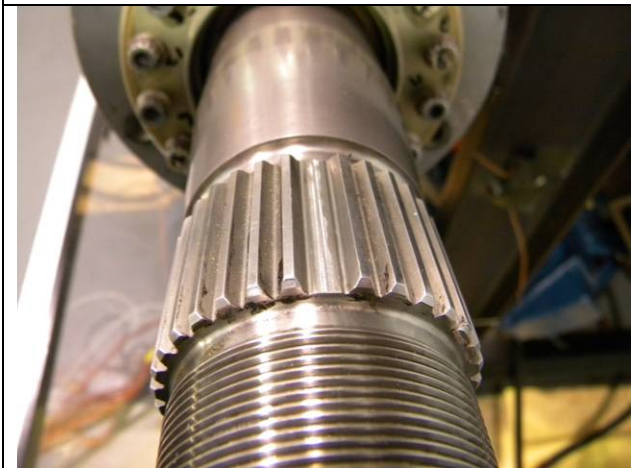
Test Photographs



T/R Test Facility With Pitch Beam



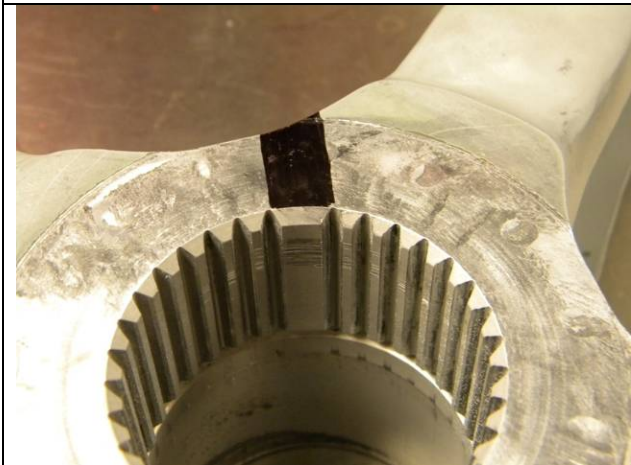
Pre-Test Pitch Change Shaft



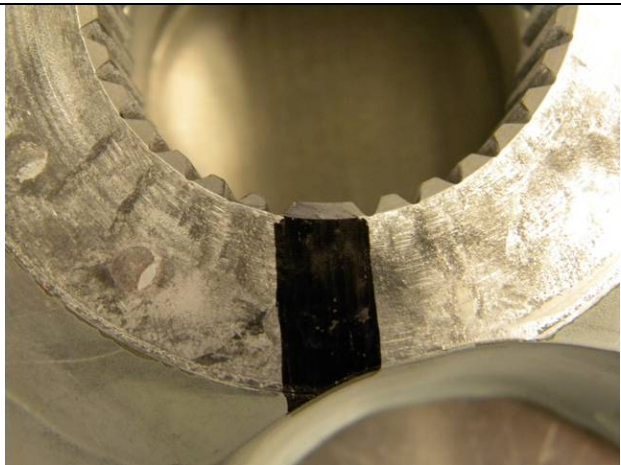
Pitch Change Shaft Index Wide Tooth



Pitch Change Shaft Pre-Test Damaged Tooth



Pitch Beam Index Marking



Pitch Beam Index Marking



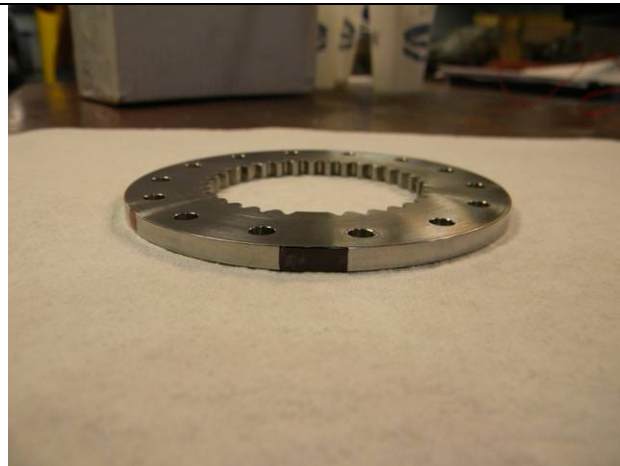
Test Photographs (Continued)



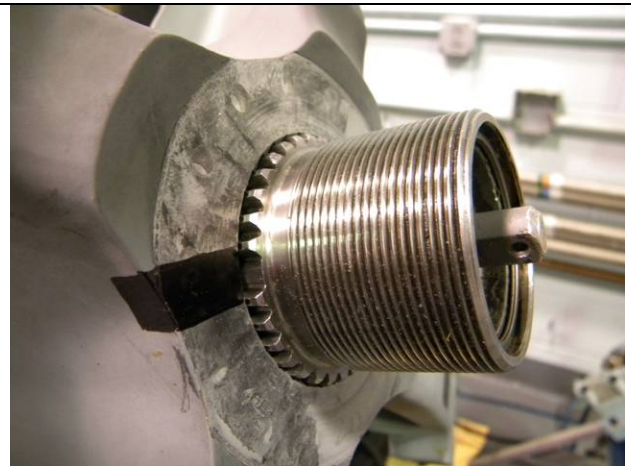
Pitch Beam Retention Nut



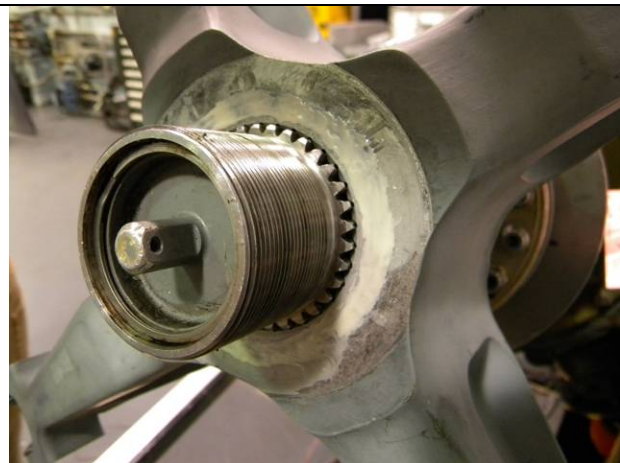
Locking Washer



Locking Washer Index Mark



Pitch Beam Mark Aligned With Index Spline



CA1000 Applied to Pitch Beam Face

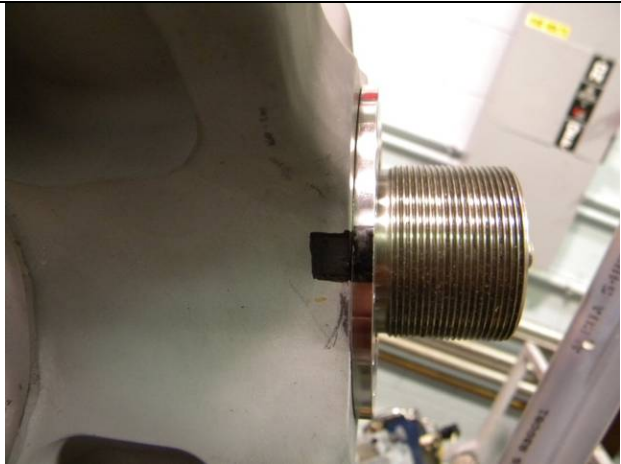


CA1000 Applied to Locking Washer

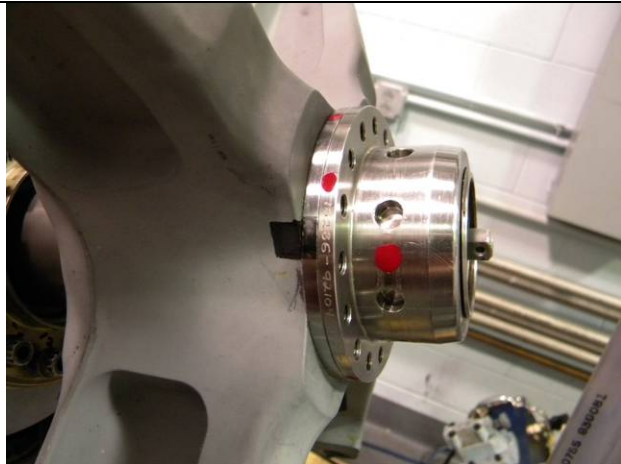
Test Photographs (Continued)



CA1000 Applied to Retention Nut



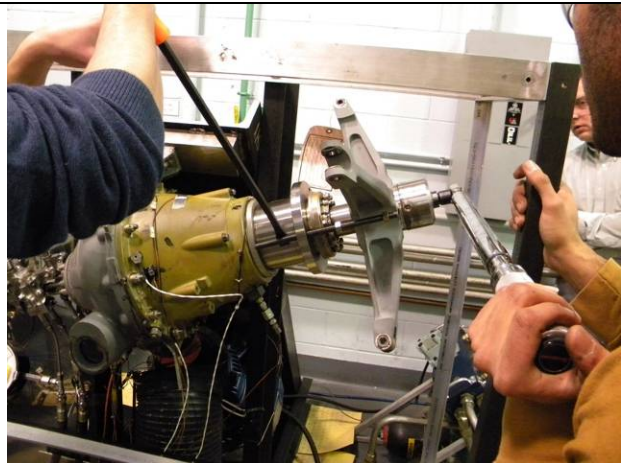
Locking Washer Installed Correctly (Aligned)



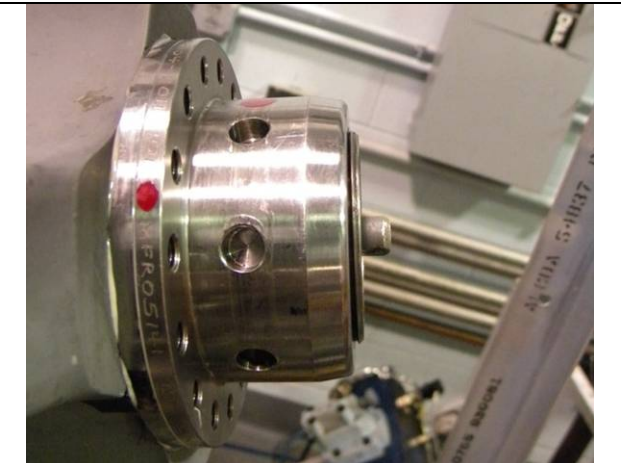
Retention Nut Correctly Installed, 0 ft\*lbs



Measuring Thread Protrusion From Nut



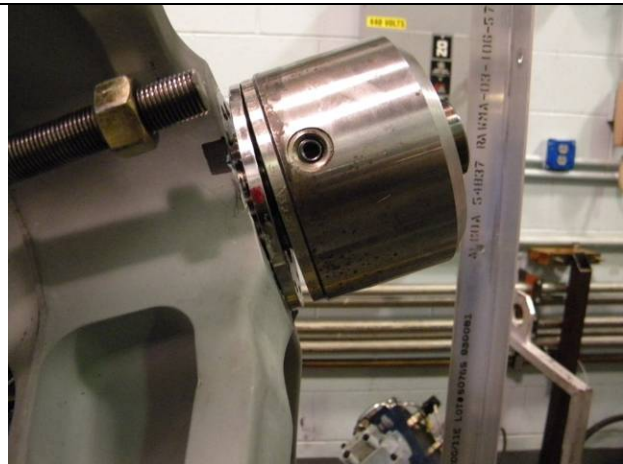
Applying Torque To Retention Nut



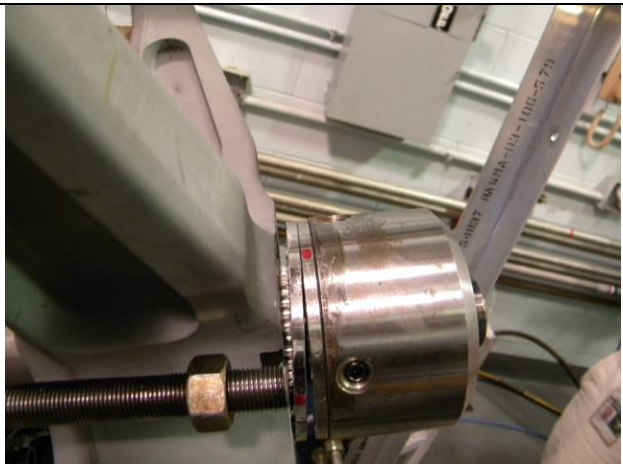
Retention Nut Correctly Installed, 202 ft\*lbs



Test Photographs (Continued)



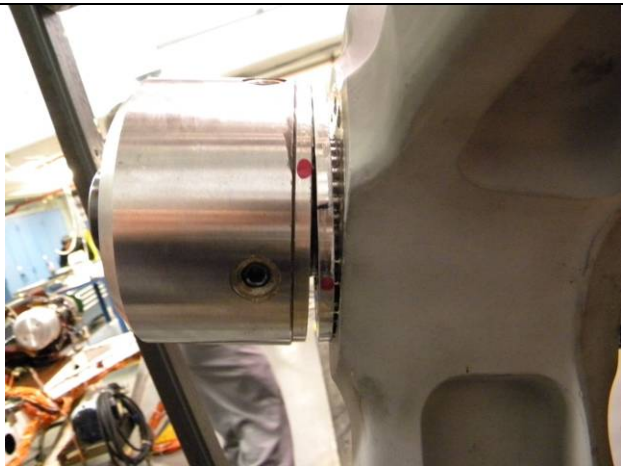
Locking Washer Misaligned on Shaft Spline



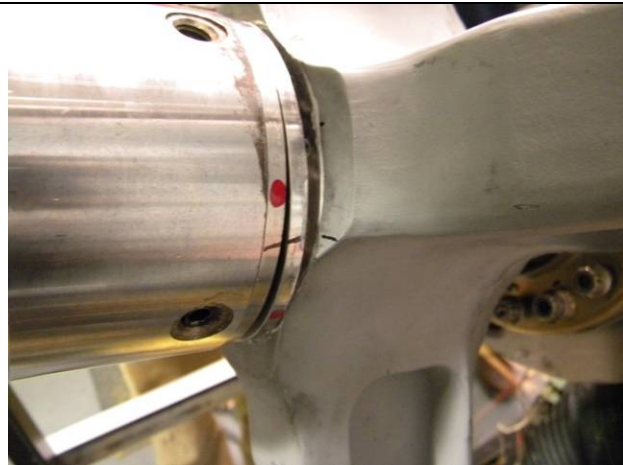
Retention Nut Incorrectly Installed, 0 ft\*lbs



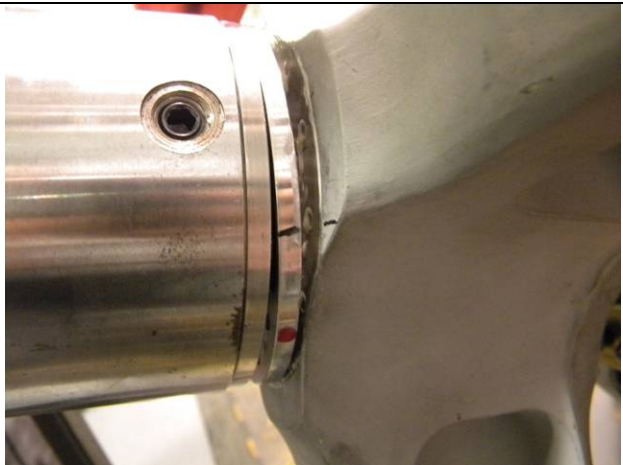
Locking Washer / Retention Nut Gap



Locking Washer Cocked Condition on Spline



Rotation Measuring Marks, 0ft\*lbs

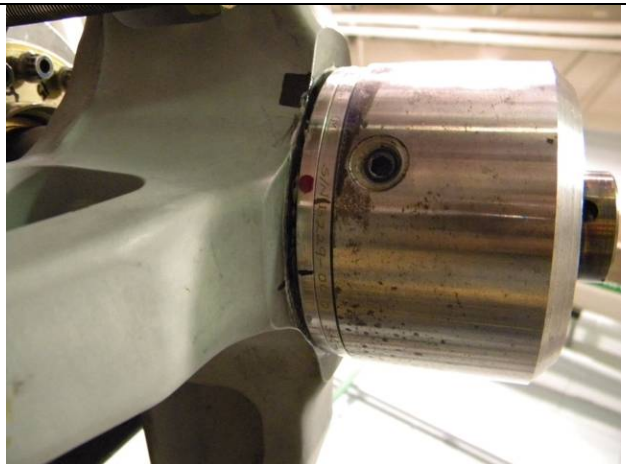


Misalignment at 60 ft\*lbs

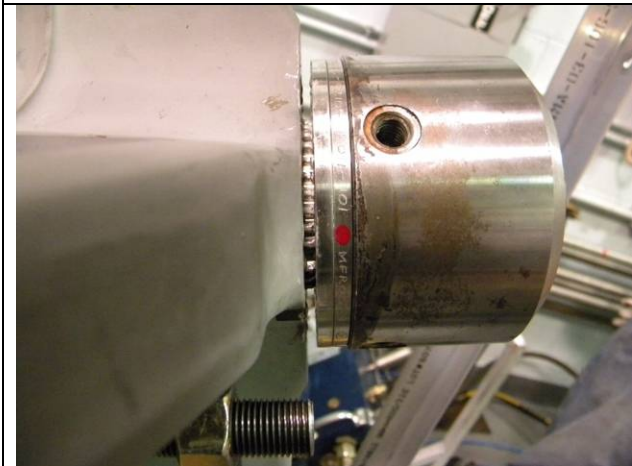
Test Photographs (Continued)



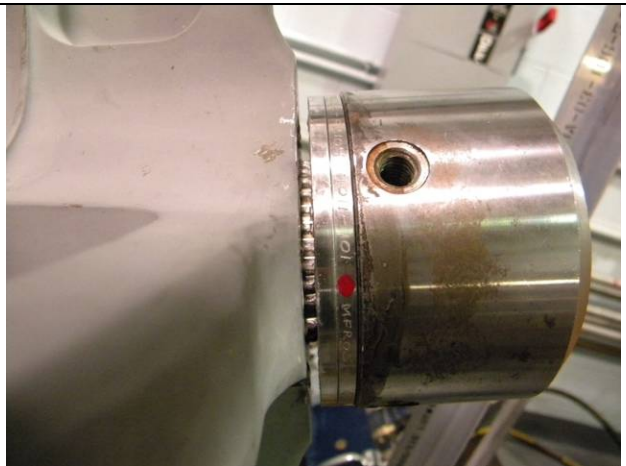
Misalignment at 120 ft\*lbs



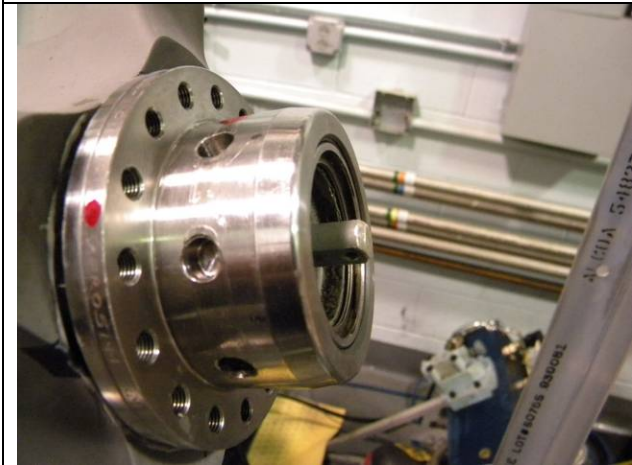
Misalignment at 183 ft\*lbs



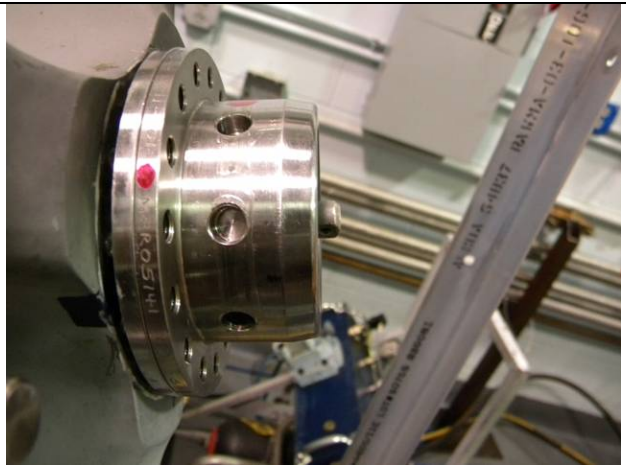
Misalignment at 183 ft\*lbs



Misalignment at 202 ft\*lbs



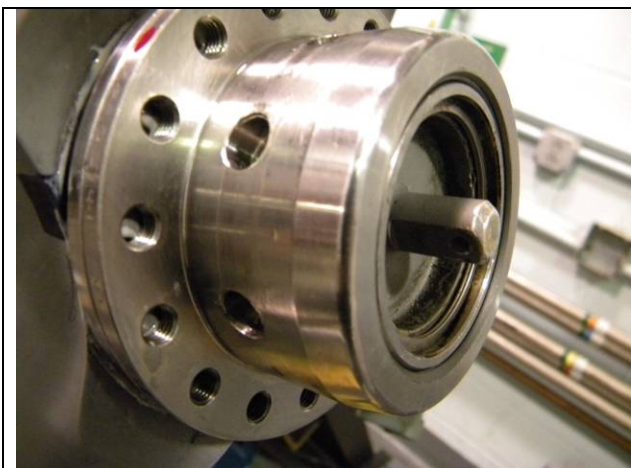
Misalignment at 202 ft\*lbs W/O Tool on Nut



Incorrect Complete Installation, 202 ft\*lbs



Test Photographs (Continued)



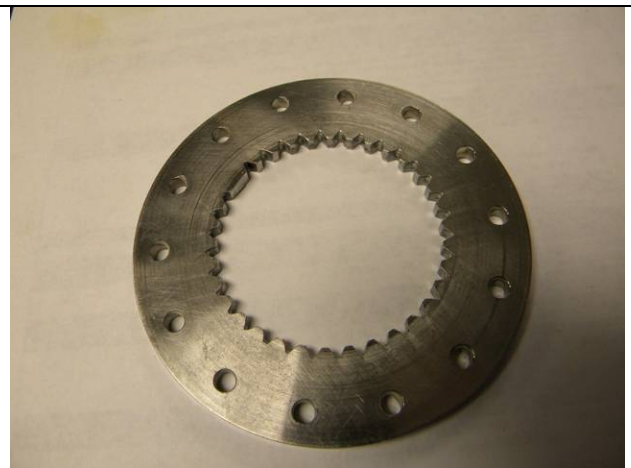
Negative Thread Protrusion, 202 ft\*lbs



Negative Thread Protrusion, 202 ft\*lbs



Post-Test Photo of Pitch Beam



Post-Test Photo of Locking Washer

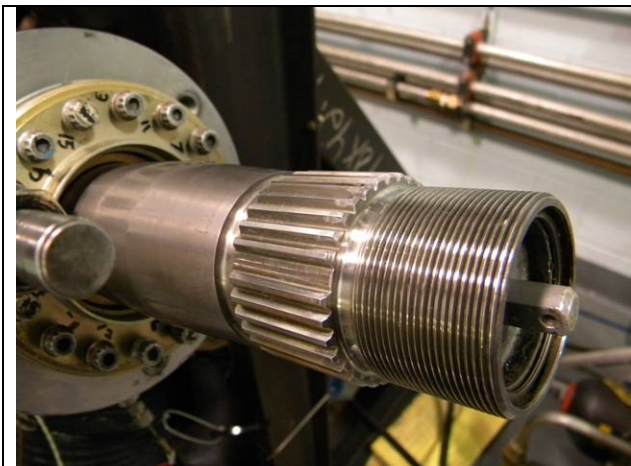


Post-Test Photo of Locking Washer

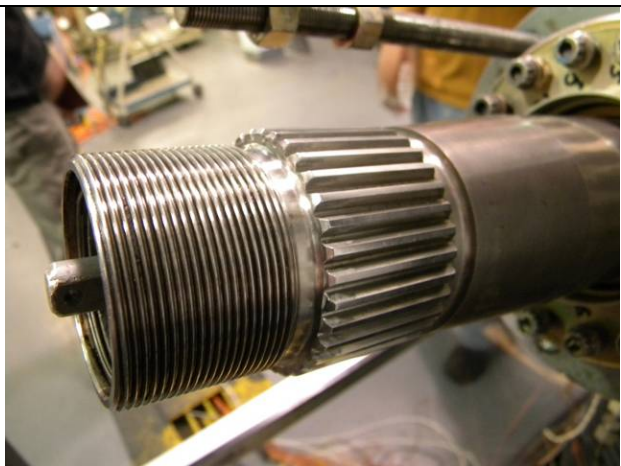


Post-Test Photo of Retention Nut

Test Photographs (Continued)



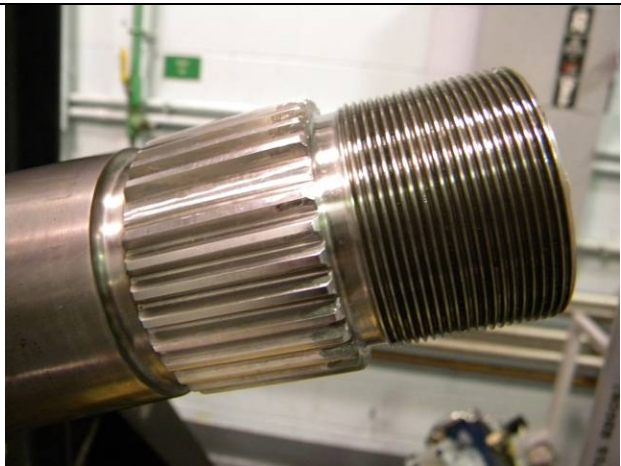
Post-Test Photo of Pitch Change Shaft



Post-Test Photo of Pitch Change Shaft



Post-Test Photo of Pitch Change Shaft



Post-Test Photo of Pitch Change Shaft